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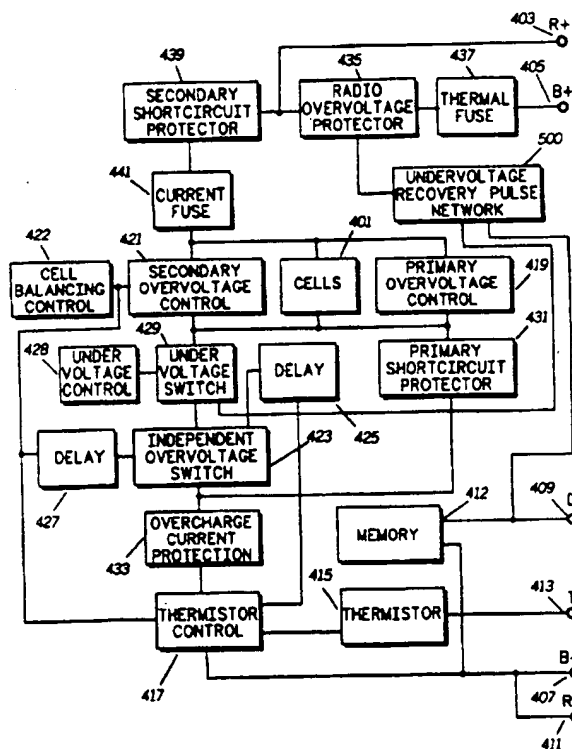
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(71) Applicant: MOTOROLA INC. [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).		
(72) Inventors: FERNANDEZ, Jose, M.; 640 Rosehill Lane, Lawrenceville, GA 30244 (US). MEADOWS, Vernon; 4745 Bridgewater Drive, Lilburn, GA 30247 (US). GARRETT, Scott, M.; 840 Station View Run, Lawrenceville, GA 30243 (US). LAM, Dao, N.; 1857 N.W. 109 Avenue, Plantation, FL 33322 (US). KAMKE, James, F.; 153 W. Lincoln Avenue, Libertyville, IL 60048 (US).		
(74) Agents: HILLMAN, Val, Jean, F. et al.; Motorola Inc., Intellectual Property Dept., 8000 West Sunrise Boulevard, Fort Lauderdale, FL 33322 (US).		

(54) Title: APPARATUS FOR SIMULATING HIGH BATTERY TEMPERATURE FOR RECHARGEABLE BATTERY SYSTEMS

(57) Abstract

A battery system (400) for use with portable electronic products which includes protection circuitry for allowing the battery system to be safely recharged in a recharging system. The battery system (400) includes cells (401) and a plurality of controls including an overcharge protection circuit (433) for limiting the amount of current to the cells (401) by a charging network and a thermistor (415) and thermistor control (417) for controlling the state of the thermistor (415) to simulate a high temperature condition allowing the charging network to switch modes and accommodate battery system (400) which does not follow the charging regimen provided by charging system.



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APPARATUS FOR SIMULATING HIGH BATTERY TEMPERATURE FOR RECHARGEABLE BATTERY SYSTEMS

5 Cross Reference to Related Applications

This application is related to co-pending applications, Docket No. EN10144, entitled "Apparatus and Method of Simulating High Battery Temperature In A Rechargeable Battery", Docket No. EN10157 entitled "Apparatus and Method of Providing an Initiation Voltage To A Rechargeable Battery System", Docket No. EN10177 entitled "Apparatus For Simulating High Battery Temperature Used In Recharging Lithium Ion Cells" and assigned to Motorola, Inc.

Technical Field

15 This invention relates in general to battery recharging and more particularly to systems for rechargeable battery cells.

Background

An increasing number of portable electronic products are available today which operate on a battery source within the device. These products include such things as cellular telephones, portable radios, pagers and voice recorders which are conveniently mobile and operate using rechargeable batteries. Many different battery chemistries have been used for many years which meet the need for recharging capability. Probably the most popular chemistries include nickel cadmium and nickel metal hydride. A relatively new chemistry, however, generally referred to as lithium ion, enables a cell to be recharged while offering many advantages over other types of rechargeable cells. These benefits primarily are directed to low weight and overall size with a high energy density. One unique factor to be considered when using a lithium ion cell is its charging scheme. A lithium ion cell is not charged in the same manner as cells utilizing a nickel chemistry.

Nickel-cadmium and nickel metal hydride cells are typically charged using a rapid charge by applying a constant current until a certain event occurs. This event may be coupled to the cell reaching a predetermined high voltage, decreasing to a predetermined low voltage or an increase in the cell's temperature. This is in contrast with the lithium ion cell which

requires a two step charging process to achieve optimum performance.

The first step of this process provides that the battery charger apply a constant current level while the cell's voltage remains below a predetermined threshold. Once the voltage increases to that threshold, the
5 second step insures the battery charger is held at the threshold voltage allowing the current to decrease. Once the current decreases sufficiently to a desired level, the lithium ion cell is fully recharged.

This two step process presents a problem when considering charging lithium ion cells in a charger designed for nickel systems. Generally,
10 nickel system chargers apply only a constant current which allows the voltage of the cells to rise unimpeded. The voltage may rise to any level provided the battery does not become too hot, i.e. increase to a undesired and dangerous level. Once the nickel system battery becomes hot, the charger detects this state and switches from the rapid high current charge to
15 a value of approximately 5 - 10% that of the rapid current value. This lower current mode is generally referred to as a trickle current or trickle charge.

Hence, the charging scheme offered by current nickel system chargers will not properly charge a lithium ion cell. Should a lithium ion
20 cell be placed or forced in to the nickel system charger the result could be potentially dangerous since the lithium ion cell could quickly overheat. Therefore, the need exists for a battery charging circuit or system which can be retrofitted to the control circuitry of an existing lithium ion cell allowing the cell to safely use a nickel system charger.

25 In addition to supplying a retrofittable circuit allowing lithium ion batteries to be recharged using nickel system chargers, a complete battery system would also be useful which would supply additional systems to insure safety when recharging a lithium ion cell in this way.

30 Brief Description of the Drawings

FIG. 1 is a block diagram showing operation of the high temperature simulator in accordance with the invention.

FIG. 2 is a partial schematic diagram in accordance with a preferred embodiment of the invention showing a high temperature simulator
35 which may be used when a high current source is available.

FIG. 3 is a partial schematic diagram in accordance with a preferred embodiment of the invention showing a high temperature simulator which may be used when only a low current source is available.

5 FIG. 4 is a partial schematic diagram in accordance with a preferred embodiment of the invention showing an alternative embodiment of a high temperature simulator to that shown in FIG. 2.

FIG. 5 is a block diagram showing operation of a retrofitable charging and safety system used with a lithium ion cell in accordance with the invention.

10

Detailed Description of the Preferred Embodiment

Referring now to FIG. 1, a block diagram depicting operation of a high temperature simulator for a rechargeable battery system which can simulate a high battery temperature condition is shown. The rechargeable
15 battery may typically be one based on a lithium ion chemistry, lithium polymer chemistry or lead acid chemistry. The high temperature simulator allows a rechargeable battery to be charged using an alien charging system or charging network which generally has an incompatible charging scheme. An alien charging system may be one used with a nickel
20 cadmium or nickel metal hydride type cells and has a first mode of operation and second mode of operation. The first mode of operation is generally a quick or fast mode while the second mode is a slower or trickle charge mode. These charging systems are generally referred to as nickel system battery chargers and are configured to charge nickel metal hydride
25 or nickel cadmium cells.

As will be described in greater detail below, the preferred embodiment of the invention takes advantage of an inherent feature present with a nickel system battery charger. This feature insures that rapid charging of a rechargeable battery ceases when the appropriate control
30 information is received from the battery. This control information is related to the battery's temperature during rapid charge. When the predetermined temperature is reached, the nickel system battery charger automatically switches to a low current or trickle charge state where the rechargeable battery can be charged more slowly.

35 A preferred embodiment of the invention shows battery 100 which includes a rechargeable cell 101. As indicated above, rechargeable cell 101 may be one or more cells with a lithium ion chemistry or the like. A

control circuit 103 measures or observes the voltage of the rechargeable cell 101 while under charge by charging system 105. Charging system 105 is typically a charger used for nickel cadmium or nickel metal hydride cells. Control circuit 103 may be a comparator circuit or the like such as Motorola
5 Integrated Circuit Model No. SC371013F/FER. Once control circuit 103 determines a predetermined voltage level or voltage potential has been reached, control circuit 103 produces a control signal on control line 106. The predetermined voltage is generally a selected voltage limit which is determined by the operational voltage of the rechargeable cell 101 and may
10 depend on specific cell chemistry and/or associated charging algorithm.

The control line 106 is used to convey the control signal from control circuit 103 to each of low voltage switch 104, high voltage switch 107 and a temperature simulator device such as thermistor switch 111. Low voltage switch is used to disconnect rechargeable cell 101 in the event its voltage
15 becomes too low, and thereby preventing damage to the cell. High voltage switch 107 and a delay circuit 109 are positioned in series with charging system 105 and are used to provide an open circuit after a desired delay period when a predetermined voltage is reached during charging. The delay period is used to allow charging system 105 to react to changes in current
20 through temperature sensor or thermistor 113. Without the delay, charging system 105 may interpret the opening of high voltage switch 107 as rechargeable cell 101 being disconnected. Once this occurs, charging system 105 may turn itself off.

Thermistor switch 111 is attached to control circuit 103 and is also
25 triggered by the control signal through control line 106 to provide a short circuit to thermistor 113. As is well known in the art, the resistive value or state of thermistor 113 changes in response to temperature changes of rechargeable cell 101. Thus, the current flowing through thermistor 113 changes in relation to the ambient environment in which thermistor 113 is
30 exposed. This current flow is interpreted by the charging system 105 as a temperature value which it uses to determine when to switch charging modes. These modes are typically switched from a fast or rapid charge state, where charging rate is at a high level to a slower charge state where the charging rate is reduced. Thermistor switch 111 is attached to thermistor 113
35 and is controlled by control circuit 103. When actuated, thermistor switch 111 alters the current flow or state of thermistor 113. As indicated above, this increase in current through thermistor 113 is detected by charging system 105

as a high temperature condition. Thus, thermistor switch 111 acts as a control circuit to change the operational state of thermistor 113. Thermistor switch 111 then simulates a high temperature state of rechargeable cell 101. In response thereto, charging system 105 switches from a high rapid or substantially fast charge mode to a slow, low or trickle charge mode. Since rechargeable cell 101 was first allowed to charge to its predetermined voltage i.e. the first step of its charging scheme, the trickle charge mode now allows rechargeable cell 101 to be charged in accordance with the second step of its charging scheme. Once charging system 105 has switched to the lower current, the voltages of rechargeable cell 101 will drop slightly from their previous level due to internal resistance present within rechargeable cell 101. This lower level of current allows continued charging of the rechargeable cell while its voltage is below the threshold voltage level, until the cell becomes fully charged. However, charging using charging system 105 will generally take longer than if the ideal lithium ion charging regime were used.

FIG. 2 illustrates a schematic representation of the high temperature simulator circuit 201 typically used in a rechargeable battery 200 where control circuit 209 can sink sufficient current to an isolated or virtual ground. As is seen in FIG. 2, rechargeable battery 200 typically includes a charging voltage node 203, a temperature node 205 and a virtual ground node 207. In operation, a charging voltage is connected to the charging voltage node 203 and virtual ground node 207. A battery charging system (not shown) measures temperature through temperature node 205 to determine when to change or switch operating modes. The battery charging system may be one designed for nickel cadmium cells, nickel metal hydride cells or the like. As indicated above, low voltage switch 210 is used to prevent rechargeable cells 211 from discharging below a selected value. Conversely, when control circuit 209 detects that rechargeable cell 212 has reached a predetermined high voltage during charging, it sends a control signal through control line 211 to high temperature simulator circuit 201 and high voltage switch 217 through delay 214. High temperature simulator circuit 201 is comprised of a diode 213 and resistor 215. When the control signal enables high temperature simulator circuit 201 and high voltage switch 217, it switches the voltage at temperature node 205 from a high level to virtual ground node 207. This has the affect of pulling or lowering the voltage on temperature node 205 to a low value since current is being sunk

to virtual ground node 207. Thus, this lower voltage simulates a high temperature condition of thermistor 216. This is detected by the battery charging system on temperature node 205 as high temperature condition which enables it to switch modes. Although diode 213 could be used alone,
5 resistor 215 is used to insure the voltage on temperature node 205 is not dropped to too low a value since certain varieties of battery chargers enter a test mode under these conditions.

FIG. 3 illustrates a schematic representation of the high temperature simulator circuit 301 typically used in a rechargeable battery 300 such as a
10 lithium ion battery. High temperature simulator circuit 301 is used where control circuit 315 cannot sink a significant amount current to allow the circuit shown in FIG. 2 to be used. It should be evident to those skilled in the art the function and operation of the rechargeable cells 304, low voltage switch 306 and delay 308 are like that described in FIGs 1 and 2 above.

15 Rechargeable battery 300 utilizes a charging node 302, temperature node 303 and virtual ground node 305. The high temperature simulator circuit 301 is comprised of an N-channel MOSFET 307, resistor 309, resistor 310, P-channel MOSFET 311 and resistor 313. In operation, when control circuit 315 actuates high voltage switch 317, this biases the gate-source junction of P-channel MOSFET 311. Resistor 313 is used to pull up or increase the voltage
20 on the gate of N-channel MOSFET 307 if control circuit 315 should fail. Resistor 313 is of a sufficiently high resistance to allow only a negligible current flow through it from charging node 302 when a control signal is enabled from control circuit 315. This causes P-channel MOSFET 311 to
25 become a low resistance value and current flows through P-channel MOSFET 311, resistor 309 and resistor 310. The resulting voltage produced also biases N-channel MOSFET 307 into a low resistance state switching it to an on state. Once N-channel MOSFET 307 is switched on, resistor 316 acts to drop voltage on temperature node 303 sufficiently to indicate or simulate to
30 a battery charging system (not shown) that a high temperature condition exists. The voltage at temperature node 303 is dropped low since the current passing through this node is directed or sunk to virtual ground node 305. Thus, the voltage measured across thermistor 314 is simulated using high temperature simulator circuit 301. The configuration shown in FIG. 3 may
35 only be used if control circuit 315 cannot handle excessive current it must sink from an attached charging system. The circuit shown in FIG. 3 is more complex however it has the advantage of low current since only a negligible

amount of current flow through resistor 313 when a control signal is enabled from control circuit 315.

FIG. 4 illustrates a schematic representation of a high temperature simulator circuit 320. High temperature simulator circuit 320 is an alternative embodiment to that shown in FIG. 2 where a high current source from an attached charging system is available. It should be evident to those skilled in the art the function and operation of the rechargeable cells 322, low voltage switch 324, high voltage switch 326 and delay 328 are like that described in FIGs 1, 2 and 3 above. In the preferred embodiment, high temperature simulator circuit 320 includes an inverter gate 321, P-channel MOSFET 323 and resistor 325. In operation, like the other embodiments above, when control circuit 327 detects a high voltage condition in cells 329, a control signal is emitted on control line 331. This pulls or lowers the voltage on control line 331 to a low state which also controls the input of inverter gate 321 low. This biases P-channel MOSFET 323 turning it on. When P-channel MOSFET is turned on this pulls or lowers the temperature node 333 to a low state since temperature node 333 is effectively connected to virtual ground node 335. The value of resistor 325 is used to control and/or select the desired temperature level that is interpreted by an attached battery charging system. Thus, an attached battery charging system which is connected to temperature node 333 detects a high temperature in view of the low voltage on this node. High temperature simulator circuit 320 acts to simulate or create a false high temperature condition.

The preferred method of practicing the invention includes charging a rechargeable battery with a charging apparatus having a first mode of operation and second mode of operation whose charging scheme is incompatible with the rechargeable cell within said rechargeable battery. The steps include applying a charging current from the charging apparatus to the rechargeable cell. Detecting a voltage potential of the rechargeable cell. Measuring the temperature of the rechargeable cell using a temperature sensor and sending a control signal from a first control network to a second control network when a predetermined voltage potential is reached to allow the temperature sensor to simulate a high temperature to the charging apparatus. Finally, sensing a simulated high temperature of the charging apparatus to change from said first mode of operation to the second mode of operation allowing the rechargeable cell to charge at a slower rate.

Thus, hot battery simulator apparatus and method disclosed will enable a new generation of lithium cell chemistries to be used without the burden of the consumer having to purchase a special charger to accommodate and recharge these rechargeable cells such as lithium ion
5 cells. This will more greatly enhance the benefits and advantages of utilizing lithium based cells keeping overall cost low as opposed to buying a completely new charger and batteries for any desired application.

FIG. 5 shows a block diagram of a lithium ion battery safety and control circuit platform or battery system 400. This system has been
10 developed for use in future lithium ion batteries, as well as a retrofit for batteries currently in use. The system is intended to accommodate various user and manufacture recommendations for providing a useful and safe lithium ion battery system that can be charged with an existing charger designed only for nickel battery systems.

15 The battery system 400 for use with a portable electronic device includes protection circuitry for one of more cells 401. Cells 401 are generally lithium ion or the like and provide a voltage potential at operating terminals 403 and 411. Operating terminals 403, 411 are used to supply an operating voltage to a portable product (not shown) which uses battery
20 system 400 for a power source. The system further includes charging terminals 405, 407 which are used to receive a charging voltage which is applied to recharge cells 401. A data terminal 409 supplies information to a charging system from a memory 412. Memory 412 is a ROM type memory or the like and conveys information to those types of chargers known as "smart
25 chargers". This information is relating to the battery type and charging regime which a charging system would be require to know before recharging the battery. Finally, a temperature terminal 413 is used to allow the charging system to detect the temperature of the battery during recharging. This is accomplished through the use of a thermistor 415 or like device which
30 permits measurement by the charging system of an accurate battery temperature during the recharging process. A thermistor control 417 is attached to thermistor 415 and is controlled by primary overvoltage control 419 and secondary overvoltage control circuit 421 to change or redirect the current flow around thermistor 415. Thermistor control 417 is discussed in
35 more detail above and has the effect of simulating a high temperature condition of cells 401. This is subsequently detected by an attached charging

system (not shown) allowing it alter its charging mode of operation from a fast charge to a slower or trickle charge.

Primary overvoltage control 419 is connected with cells 401 and is used to measure the cumulative voltage present on the cells 401 to prevent the cells from increasing or rising above a selected voltage. In the event
5 primary overvoltage control 419 fails or becomes inoperative, secondary overvoltage control 421 is used to measure the voltage on each individual cell and prevent each individual cell from increasing or rising above a selected voltage. Upon actuation of either primary overvoltage control 419
10 or secondary overvoltage control 421, a control signal is supplied to one or more independent overvoltage switches 423. Actuation of any one of independent overvoltage switches 423 provides an open circuit which disconnects cells 401 from operating terminals 403, 411. Each control signal is delayed using a delay 425 or delay 427 respectively which delays the
15 control signal before actuating any of independent overvoltage switches 423. The delay 425, 427 is used to insure thermistor control 417 receives its control signal before independent overvoltage switches 423 are enabled which would disconnect the charge current from cells 401. This allows an attached charging system to detect simulated changes in the temperature of
20 cells 401 and alter its mode of operation before actuating any of independent overvoltage switches 423. Similarly, 428 is used to measure the cumulative voltage of cells 401 and provides a control signal to undervoltage switch 429 when the cumulative voltage drops below a predetermined level. Like independent overvoltage switches 423, undervoltage switch 429 is connected
25 serially with cells 401 and disconnects cells 401 when the voltage of the cells drops to an undesirably low level to prevent damage to cells 401.

Cell balancing control 422 is comprised a load (not shown) connected in parallel with each of cells 401. Cell balancing control 422 acts to switch the load across a cell in order to maintain each of the cells at approximately the
30 same voltage level during charging. The load is used to slightly discharge a single cell in the event the cell becomes a slightly higher voltage as compared with other cells. The load is disconnected once the cell voltage has been reduced to a level compatible with other cells.

Primary short circuit protector 431 is used to measure the voltage
35 across both independent overvoltage switches 423 and undervoltage switch 429. Since these switches inherently have a stable DC resistance, the voltage across them is proportion to the current which runs through them when.

cells 401 are being recharged. When the current through independent overvoltage switches 423 and undervoltage switch 429 reaches a predetermined i.e. excessive level, this also drops the voltage across these switches. In response to a selected voltage drop across independent
5 overvoltage switches 423 and undervoltage switch 429, primary short circuit protector 431 provides a control signal to undervoltage switch 429. This insures the undervoltage switch 429 disconnects cells 401 from terminals 403-411 to prevents any further discharge until the excessive high current conditions removed. This acts as a safety feature to prevent cells 401 from
10 generating excessive heat and possible damage under extremely high load conditions.

Overcharge current protector 433 is a complement to primary short circuit protector 431 by directly measuring the amount of current through it. If the current reaches a selected level, a control signal is generated by
15 overcharge current protector 433 to independent overvoltage switches 423 which disconnects cells 401 from terminals 403-411. Additionally, overcharge current protector 433 is used to limit the charge current. Since cells 401 is a lithium ion type cell and is used with a charger designed with a charging regimen for nickel chemistry cells, it often may charge at a current
20 level higher than at the optimum level for a lithium ion cell. In this case, overcharge current protector 433 will detect this high current level and provide a control signal to thermistor control 417 to simulate a high temperature condition. This tricks the nickel system charger and forces it into a low current or trickle charge mode which is more suited for the
25 lithium ion cell.

Electronic device overvoltage protector 435 is connected serially with cells 401 and charging terminal 405 and is used to determine when any of independent overvoltage switches 423 have been actuated. Since actuation of these switches may cause the voltage of cells 401 to increase or rise to a
30 level which could damage electronic equipment attached to the battery system 400 at operating terminals 403, 411 electronic device overvoltage protector 435 detects actuation of independent overvoltage switches 423 and in response thereto, disconnects operating terminal 403, from charging terminal 405 to prevent an attached charger from supplying a potentially
35 damaging voltage to an electronic device attached to operating terminal 403. Alternatively, if electronic device overvoltage protector 435 is not used, a thermal fuse 437 may be implemented. Thermal fuse 437 is also attached

serially between cells 401 and charging terminal 405 and is generally a high power zener diode (not shown) or the like. The zener diode acts to shunt current when cells 401 are above a selected voltage since this would likely damage an electronic device attached to operating terminal 403.

5 A secondary short circuit protector 439 acts as a current detection element and is also connected in series between cells 401 and operating terminal 403 and charging terminal 405. Secondary short circuit protector 439 may be a polyswitch or the like and is used to detect excessive current which may not be detected by either primary short circuit protector 431 or
10 overcharge current protector 433.

Finally, a current fuse 441 also acts as a current detection element and is placed in series between cells 401 and operating terminal 403 and charging terminal 405 and is used as a last resort or ultimate backup in the event of a catastrophic failure in which current rises to an unacceptable level. The fuse
15 is generally located close to cells 401 to minimize runner length. The current fuse 441 is preferably a slow acting type so as not to interfere with other current protection systems with lithium ion battery system 400.

Finally, undervoltage recovery pulse network 500 is used in the event that any one of independent overvoltage switches 423 have been actuated
20 and cells 401 are no longer connected to charging terminal 405. Under these conditions, when the battery is initially connected to a charging system (not shown), the charging system first detects a voltage present on charging terminals 405, 407. If no voltage is present, the charging system determines that no battery is connected to it and does not provide a charging voltage to
25 operating terminals 403, 411. When the battery is initially connected however, an initial pulse of a predetermined voltage and amplitude is supplied from the charging system to data terminal 409. This pulse is detected by undervoltage recovery pulse network 500 which utilizes the voltage to restore operation of independent overvoltage switches 423. Once
30 operation of independent overvoltage switches 423 is restored, the appropriate switch is closed which restores continuity between cells 401 and charging terminal 405 through electronic device overvoltage protector 435. Thus, the voltage of cells 401 is restored in a time fast enough that a charging system will detect this voltage on operating terminals 403, 411 even when a
35 battery system 400 is disabled, and cells 401 disconnected due to some event which has occurred. The charging system will recognize the voltage on

charging terminals 405, 407 and begin a charging cycle by applying a charging voltage to these terminals.

While the preferred embodiments of the invention have been illustrated and described, it will be clear that the invention is not so limited.

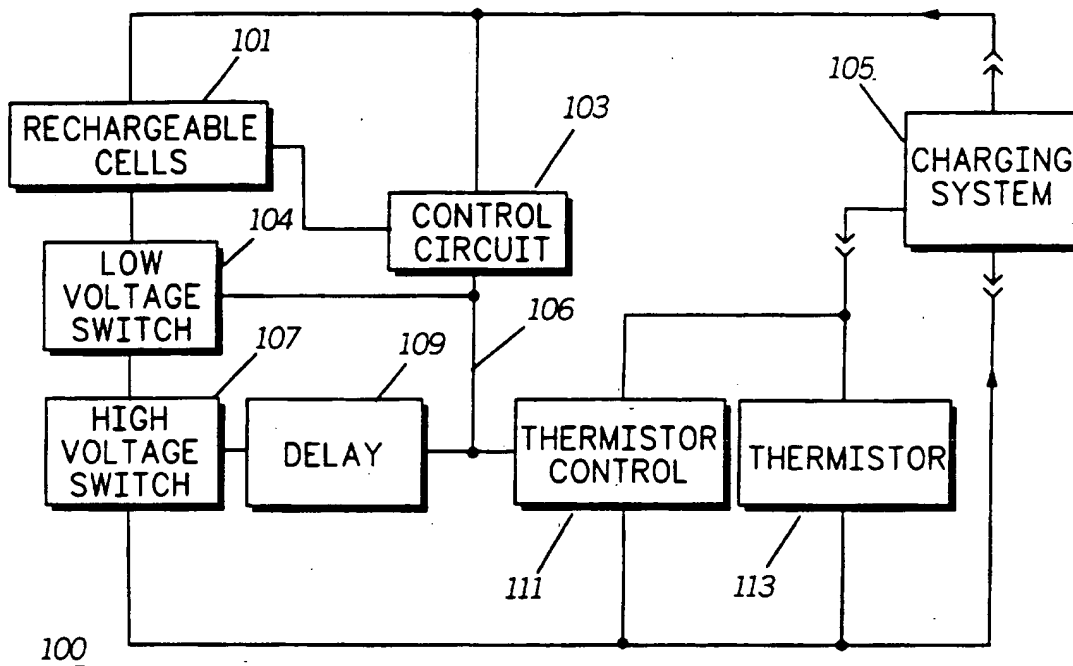
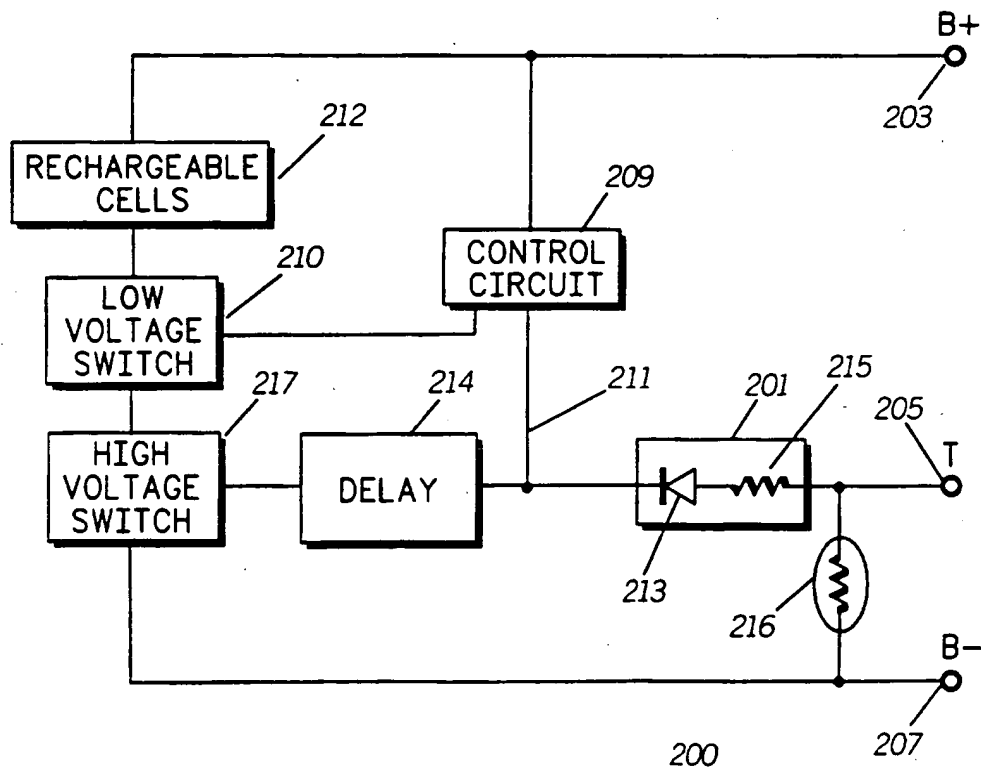
- 5 Numerous modifications, changes, variations, substitutions and equivalents will occur to those skilled in the art without departing from the spirit and scope of the present invention as defined by the appended claims.

Claims:

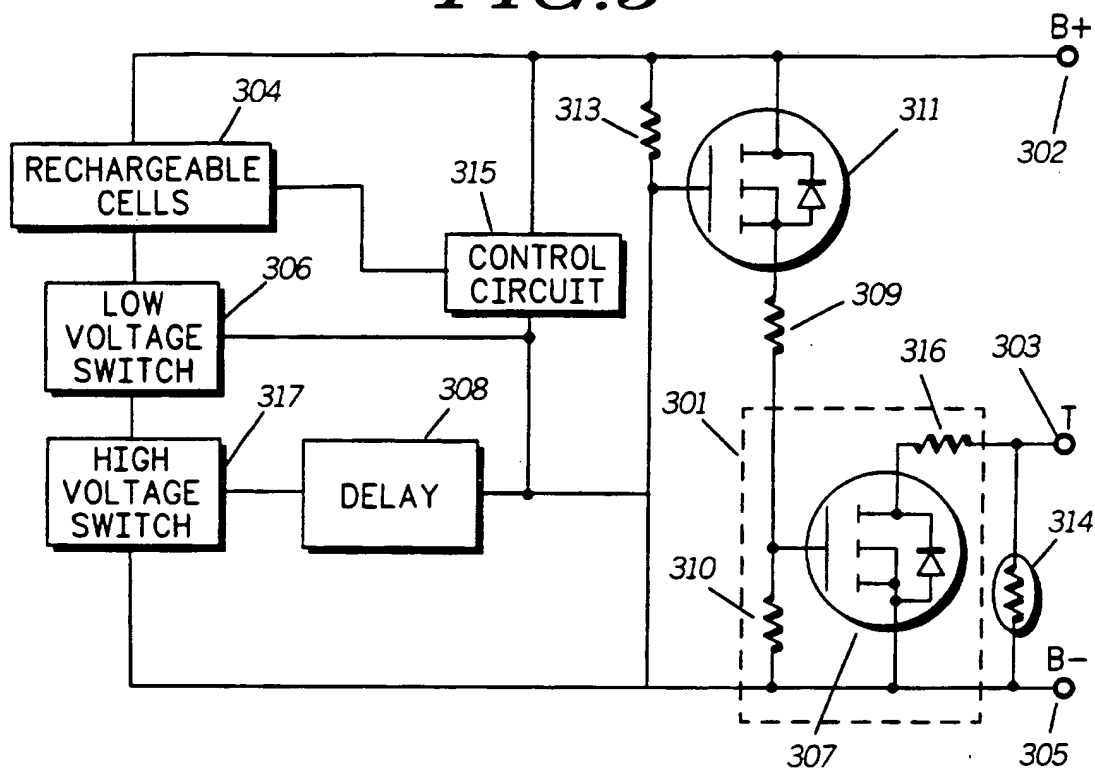
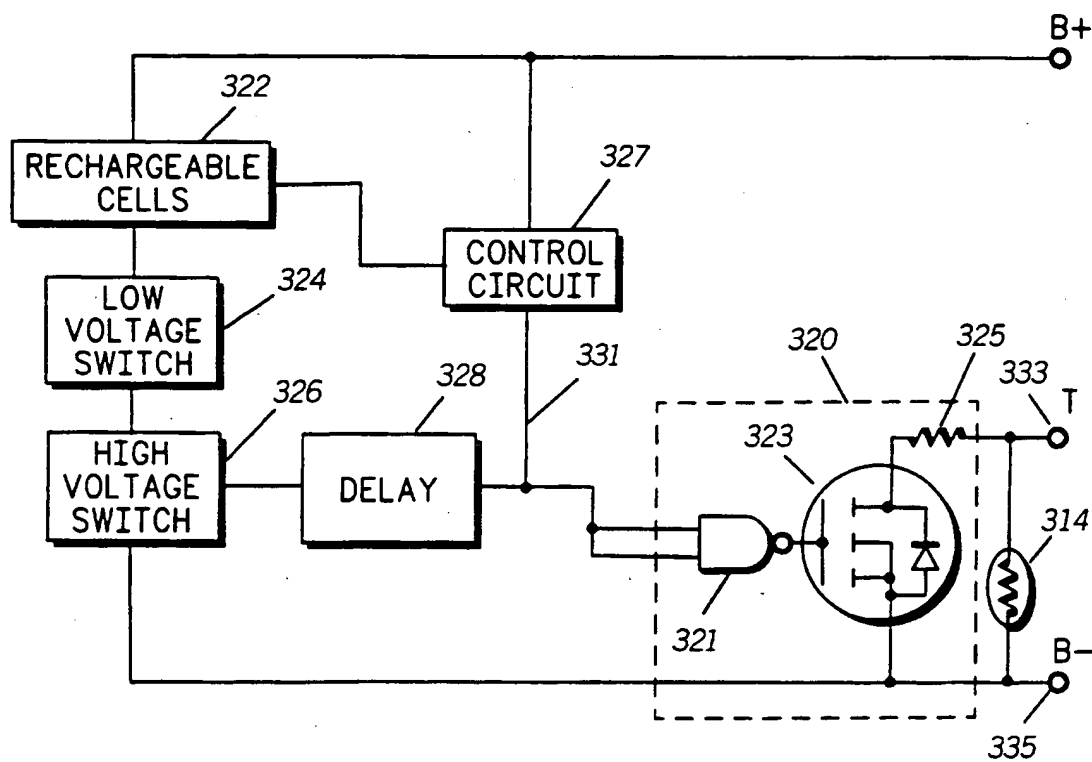
1. A lithium ion battery system for use with a portable device comprising:
 - a plurality of lithium ion cells;
 - a plurality of switches connected to said plurality of lithium ion cells
 - 5 for disconnecting said plurality of lithium ion cells from said portable device;
 - a current detector for detecting a short circuit and actuating at least one of said plurality of switches;
 - a primary cell overvoltage detector for monitoring a cumulative
 - 10 voltage of said plurality of lithium ion cells and actuating at least one switch of said plurality of switches if said cumulative voltage increases above a predetermined level;
 - a secondary cell overvoltage detector for monitoring an individual voltage of said plurality of lithium ion cells and actuating at least one
 - 15 switch of said plurality of switches if said individual voltage increases above a predetermined level;
 - a cell undervoltage detector for monitoring the cumulative voltage of said plurality of lithium ion battery cells and actuating at least one switch of said plurality of switches if said cumulative voltage decreases below a
 - 20 predetermined level; and
 - a thermistor for detecting the temperature of said lithium ion cells.
2. A lithium ion battery system as in claim 1 further comprising:
 - a thermistor control simulator for controlling a current flowing
 - 25 through said thermistor to allow said thermistor to indicate a false temperature reading.
3. A lithium ion battery system as in claim 2 wherein said temperature reading is a high temperature reading which is monitored by a charging
- 30 system.
4. A lithium ion battery system as in claim 1 further comprising:
 - a cell balancing controller for maintaining each cell of said plurality of lithium ion cells at substantially an equal voltage during charging.

5. A lithium ion battery system as in 1 further comprising:
device overvoltage detector for monitoring actuation of at least one
of said plurality of switches and disconnecting said portable device from
5 said plurality of lithium ion cells in response thereto.
6. A lithium ion battery system as in claim 1 further comprising a memory
circuit of supplying charging information of said plurality of lithium ion
cells to a charging system.
- 10 7. A lithium ion battery system as in claim 1 further comprising a delay
circuit for delaying actuation of said at least one switch when actuated by
said primary cell overvoltage detector.
- 15 8. A lithium ion battery system as in claim 7 further comprising a delay
circuit for delaying actuation of said at least one switch when actuated by
said secondary cell overvoltage detector.
- 20 9. A lithium ion battery system as in claim 1 further comprising a portable
device operating terminal, charging voltage terminal, charging
information terminal and temperature information terminal for
conveying information to said portable device and charging system.
- 25 10. A lithium ion battery system as in claim 9 further comprising:
a current detector connect serially with said plurality of lithium ion
cells for disconnecting said plurality of lithium ion cells from said portable
device voltage terminal and said charging voltage terminal.
- 30 11. A lithium ion battery system as in claim 10 wherein said current
detector is a current fuse.

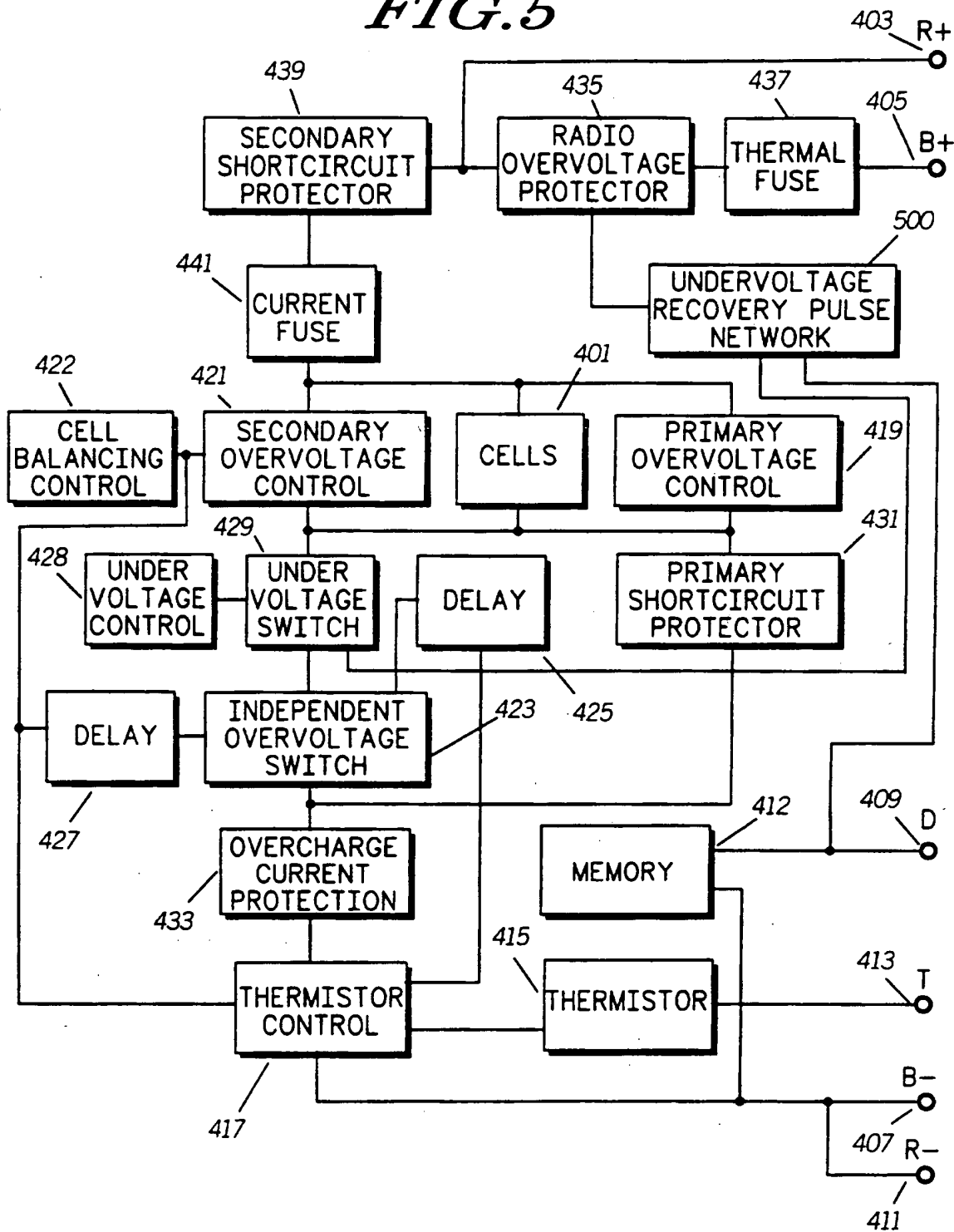
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FIG.1**FIG.2**

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FIG. 3**FIG. 4**

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FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US95/15480

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H01M 10/48.

US CL : 320/18, 35.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 320/6, 15, 18, 30, 35, 36, 39 AND 40.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,303,877 (MEINHOLD) 01 DECEMBER 1981 SEE ENTIRE TEXT	1-11
Y, P	US, A, 5,410,238 (ISHIZUKA ET AL.) 25 APRIL 1995 SEE FIGURES	1-11

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

EDWARD H TSO

Telephone No. (703) 308-1782